

**IMPROVING THE THERMAL STABILITY OF AMMONIUM NITRATE BASED
ON LOCAL RAW MATERIALS**

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Abstract. This article investigates methods for improving the thermal stability of ammonium nitrate based on local raw materials extracted in Uzbekistan — phosphogypsum, bentonite, and potassium chloride. Experimental results show that adding 3–5% of a phosphogypsum–bentonite mixture increases the decomposition temperature of ammonium nitrate from 184°C to 196°C. New composite formulations are proposed to suppress critical phase transitions and reduce hygroscopicity. The obtained results offer the possibility of producing more stable and safer ammonium nitrate for the heavy industry and agricultural sectors.

Keywords: ammonium nitrate, thermal stability, phosphogypsum, bentonite, critical transition temperature, composite formulation, local raw materials.

Annotatsiya. Ushbu maqolada O'zbekiston hududida qazib olinadigan mahalliy xom ashyolar — fosfogips, bentonit va kaliy xlorid asosida ammoniy nitratning termik barqarorligini oshirish usullari tadqiq etilgan. Eksperimental natijalar shuni ko'rsatadiki, fosfogips va bentonit aralashmasini 3–5% miqdorida qo'shilishi ammoniy nitratning parchalanish haroratini 184°C dan 196°C gacha oshiradi. Shu bilan birga, kritik harorat o'tishlarini bostirish va nam tortish xususiyatini kamaytirish bo'yicha yangi kompozitsion tarkiblar taklif etilgan. Olingan natijalar og'ir sanoat va qishloq xo'jaligi tarmoqlari uchun yanada barqaror va xavfsiz ammoniy nitrat ishlab chiqarish imkonini beradi.

Kalit so'zlar: ammoniy nitrat, termik barqarorlik, fosfogips, bentonit, kritik o'tish harorati, kompozitsion tarkib, mahalliy xom ashyo.

1. Introduction

Ammonium nitrate (NH_4NO_3) is one of the most important chemical compounds widely used in the mineral fertilizer and explosive materials industries. Worldwide, more than 150 million tons of ammonium nitrate are produced annually. However, one of the main challenges associated with this substance is its low thermal stability and the transformation of its crystal structure at several critical phase-transition temperatures. As a result, product quality deteriorates during storage, granulation, or moisture exposure, potentially leading to serious safety issues [1, 2].

In Uzbekistan, ammonium nitrate is primarily produced at chemical industry enterprises in Fergana and Chirchiq. Incorporating local raw material resources — in particular, Karatau phosphogypsum, Navoi bentonite, and products from the Kangurt potassium deposits — as additives in ammonium nitrate production holds significant scientific and practical value [3]. This study is aimed at investigating the potential for improving the thermal stability of ammonium nitrate by introducing locally sourced mineral additives.

2. Literature Review

Numerous foreign and domestic studies exist on the thermal properties of ammonium nitrate. Vargeese and Trigg (2012) examined the decomposition mechanisms of ammonium nitrate from a thermodynamic perspective, confirming that the reaction $\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2\text{O} + 2\text{H}_2\text{O}$ represents the primary decomposition pathway [4]. Chen et al. (2019) studied the effects of various additives (SiO_2 , MgO , dolomite) and demonstrated that mineral additives can significantly raise the decomposition temperature [5].

Among domestic studies, the work of Mirzayev M.M. and Qodirov B.Kh. (2018) on the use of Navoi bentonite as a plasticizer is particularly noteworthy [6]. However, the combined effect of phosphogypsum and bentonite — and specifically the mechanism by which critical phase transitions (phases I, II, III, and IV) are suppressed — remains insufficiently studied. For this reason, the present research is both topical and original.

3. Research Methodology

The following raw materials were used in the study: standard industrial NH_4NO_3 (99.5% purity); Karatau phosphogypsum waste ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, 94%); Navoi bentonite (Na-bentonite, swelling index 18 ml/g); and potassium chloride (Kangurt, 98%). Samples were prepared at varying additive proportions (1%, 3%, 5%, 7%) and dried under identical conditions at 80°C. Thermal analysis was carried out using a TGA/DSC instrument (Netzsch STA 449) in a nitrogen atmosphere at a heating rate of 10°C/min over the range 30°C to 400°C.

To evaluate the effect of moisture, isothermal conditioning was performed at 75% relative humidity for 48 hours. Mechanical strength was assessed using the Marshall compression method, and crystal morphology was examined by SEM (Hitachi S-3400N). Safety parameters were evaluated in accordance with the Belgian BN EN 13631 standard.

4. Results and Discussion

The TGA/DSC analysis results are presented in tabular form below (Table 1). Pure ammonium nitrate exhibited four critical phase transitions at 84°C, 127°C, 170°C, and 210°C. When a phosphogypsum–bentonite mixture (3:1 ratio) was added at the 3% level, a marked suppression of the phase II transition at 127°C was observed.

Sample Composition	Decomposition Temperature (°C)	Phase II Transition (°C)	Mass Loss (%)	Moisture Absorption (%)
Pure NH_4NO_3	184	127	99.8	4.2
NH_4NO_3 + 3% phosphogypsum	189	131	99.6	3.5
NH_4NO_3 + 3% bentonite	191	133	99.4	2.8
NH_4NO_3 + 3% (PG+B, 3:1)	196	138	99.1	2.1
NH_4NO_3 + 5% (PG+B, 3:1)	198	140	98.8	1.8

Table 1. Thermal parameters of ammonium nitrate samples prepared with various additives (PG — phosphogypsum, B — bentonite).

The table results clearly show that the phosphogypsum–bentonite combination is significantly more effective than the individual additives. The synergistic effect is explained as follows: Ca^{2+} ions from phosphogypsum interact with NH_4^+ , thereby increasing crystal lattice stability; while the layered silicate structure of bentonite reduces thermal conductivity and slows the decomposition process [5, 7].

Moisture absorption indicators also showed considerable improvement: with the 3% combined additive, moisture absorption decreased from 4.2% to 2.1%. This substantially reduces the problem of caking during storage and transportation. The 5% additive also yielded good results; however, it should be noted that additive quantities exceeding the optimal level may reduce the product's key chemical parameters (nitrogen content).

5. Conclusion

The research results demonstrate that Uzbekistan's local mineral raw materials — phosphogypsum and bentonite — can effectively serve as additives for improving the thermal stability of ammonium nitrate. A 3:1 mixture of phosphogypsum and bentonite at a 3–5% dosage is recommended as the optimal formulation. This composition raises the decomposition temperature from 184°C to 196°C, shifts the critical phase II transition from 127°C to 138°C, and reduces moisture absorption by 50%.

These results hold practical significance for ammonium nitrate-producing enterprises in Uzbekistan, offering opportunities to reduce import dependency and make effective use of local raw materials. The next phase of research will focus on conducting large-scale industrial trials of the proposed composite formulations and pursuing certification under the UN Test Series safety passport framework.

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